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A brushing apparatus was designed and built to simulate the cleaning processes of ship hulls. Wear was measured with a profile meter. The proposed methodology is valuable to study the processes of wear of the coatings, to screen various materials and to identify parameters, either functional or material, which would directly affect their durability. Two groups of coatings were tested: the EXS series and the NRL series. The EXS samples showed better wear resistance than the NRL samples and showed no dependence on the rotational speed of the brushes. The NRL samples showed that increasing the sliding speed resulted in a decrease in wear. An increase in the applied load resulted in increased wear for both sample series. The bond coat had a higher wear resistance than either of the top coats. One possible cause of the better wear resistance of the EXS coating is the fused silica filler in the coating. The NRL coatings had calcium carbonate filler particles. The wear rates of the top coats was independent of the coating thickness. Therefore, thicker coatings will have longer lives than thinner ones.

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# FINAL REPORT

GRANT #: N00014-96-1-0457

PRINCIPAL INVESTIGATOR: Dr. Norman S. Eiss Jr.

INSTITUTION: Virginia Polytechnic Institute and State University

GRANT TITLE: Durability Testing for Fouling Release Coatings

AWARD PERIOD: 1 January 1996 - 31 December 1997

OBJECTIVES: To develop a test method to evaluate the durability of elastomeric easy-release coatings using a new device which uses brushes to abrade the coatings.

To evaluate the effects of sliding speed, normal load, and coating thickness on the durability of two series of candidate coatings.

APPROACH: Several durability tests were analyzed and most were found to be unable to discriminate between different compositions of coatings because the tests were too aggressive. A method utilizing tooth brushes abrading coatings had the ability to show the effects of composition on durability. Since brushing is an accepted Navy practice for removing marine biofouling from hulls it was believed that a brushing test would be a good simulation of practice. Therefore tooth brushes rotating against a coating was used in a new apparatus in which both the normal load and sliding speed could be measured and varied.

Two series of duplex coatings were tested. The duplex coatings had an anticorrosion (AC) layer, an intermediate bond layer, and a top release layer. The purpose of the bond coat is to bond the top coat to the AC layer. The top coat in the NRL series is G.E. RTV11 and in the EXS series is G.E. Excil® 2200. The bond coat and AC coats are the same in both series, namely, Wacker Silgar® J-501 and epoxy, respectively. The AC layer was coated on a steel substrate. The coatings were prepared with four nominal ratios of top coat to bond coat thickness: 0/20, 5/15, 10/10, and 15/5. The nominal combined thickness of the top and bond coats was 20 mils.

Two tests series were run: rate tests and load-speed tests. The purpose of the rate tests was to evaluate the effect of the ratio of top coat to bond coat thickness on the wear of the coating at a load of 300 g and a rotational brush speed of 395 RPM. The purpose of the load-speed tests was to evaluate the wear of the 10/10 coatings at loads of 100 and 300g and rotational speeds of 125 and 395 RPM. All tests were performed with the coating and brushes continuously submerged in salt water made from Instant Ocean synthetic sea salt.

During the durability tests, the brushes rotated against the coating and wore a groove in the coating. Periodically, the coating was removed from the test machine and the cross section area and depth of the groove were measured with a surface profile meter.

ACCOMPLISHMENTS: The rate tests showed that the bond coat (0/20) had the lowest wear of all the coating thickness ratios, 0.00517 and 0.0123 square mils per 100 brush strokes for the NRL and EXS series, respectively. The next lowest wear rates were those of the EXS 5/15 and 10/10 samples, 0.196 and 0.138 square mils per 100 brush strokes. The highest wear rates were for the NRL 10/10 and 15/5 and the EXS 15/5, 0.739, 1.16, and 0.76 square mils per 100 brush strokes, respectively. The unexpectedly high wear rate for the EXS 15/5 was caused by air bubbles entrapped in the layer during curing.

In general, these results show that the bond coat has a wear resistance much superior to those of the NRL and EXS top coats and the EXS top coat has a wear resistance superior to that of the NRL top coat. The major composition difference between the NRL and EXS top coats is the filler composition. The NRL top coat contains calcium carbonate while the EXS contains fused silica. While the thickness of the top coat does not appear to have a significant effect on the wear rate, thicker coating will last longer than thinner coatings.

The load-speed tests showed that the wear of the NRL top coats increased with increasing normal load and decreased with increasing sliding velocity. The wear of the EXS top coats also increased with increasing normal load but there was no significant effect of changing speed on wear. While several hypotheses were proposed to explain the speed effect on the NRL coating, none could be verified as being conclusive.

CONCLUSIONS: A tester and test protocol for measuring the durability of elastomeric fouling release coatings which simulates the brushing action of hull cleaning procedures has been demonstrated. Two series of duplex coating systems were evaluated. The EXS top coat was more durable that the NRL top coat and the bond coat in both series had superior wear resistance to both top coats.

An increase in load causes an increase in wear for both the EXS and NRL top coats. An increase in sliding speed results in a decrease in the wear volume for the NRL top coats. The effect on sliding speed on the wear of EXS top coats was not statistically significant. The wear rates of the top coats were independent of the coat thickness.

The fused silica filler in the EXS top coat may contribute to its superior durability compared to that of the NRL top coat which is filled with calcium carbonate.

The thickness of the top coat determined the life of the coating.

SIGNIFICANCE: The tester and test protocol provide a method for comparison of the durability of elastomeric fouling release coating which are developed for preventing the attachment of marine organisms to ship hulls and other underwater structures such as power plant water intake screens.

PATENT INFORMATION: No patents have been applied for.

AWARD INFORMATION: Society of Tribologists and Lubrication Engineers Captain Alfred E. Hunt Award for the best paper published in the Society's journal from June 1994- May 1995. Awarded in October 1996.

PUBLICATIONS AND ABSTRACTS:

Christiaen, Anne-Claire, Evaluation of the Durability of Elastomeric Easy-release Coatings, PhD dissertation, Virginia Polytechnic Institute and State University, Blacksburg, VA. 24061, Advisor: Dr. . N. S. Eiss Jr. [ Available on line at http://scholar.lib.vt.edu/theses/available/etd-92398-04626/ ]

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**Abstract**

Novel coatings have been designed to solve problems associated with biofouling of marine structures, particularly ship hulls. The best candidates to date are multilayered coatings incorporating silicone rubber technology. These materials are efficient because they exhibit excellent release properties. However, they are very soft and tend to be more susceptible to

various forms of mechanical damage. Fundamental analysis of the durability of these coatings has been done using standard laboratory tests. Simulative studies are essential to screen candidates as well as to predict the true life of the systems. The goal of this project was to develop a testing protocol for the evaluation of the durability of elastomeric easy release coatings and to implement it on selected candidate coatings.

A brushing apparatus was designed and built to simulate the cleaning processes of ship hulls. Wear was measured with profilometry. The proposed methodology is valuable to study the processes of wear of the coatings, to screen various materials and to identify parameters, either functional or material, which would directly affect their durability.

Two groups of candidate coatings were tested: the EXS series and the NRL series. The EXS samples showed better wear resistance than the NRL samples and showed no dependence on the rotational speed of the brushes. The NRL samples showed that increasing the sliding speed resulted in a decrease in wear. An increase in the applied load resulted in increased wear for both sample series. The effect of coating thickness was also investigated and discrimination between the proposed coatings could not be established because the tips of the bristles were sharp and irregular. Scratches matching the path of the brush bristles were observed in the wear scars of both sample types under all load and speed conditions. The NRL samples also exhibited ridges perpendicular to the sliding direction similar to the abrasion pattern.

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